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Improving fertilizer recommendations for Nepalese farmers with the help of soil-testing mobile van

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Abstract

Smallholder farmers dominate agriculture in Nepal. These farmers have poor knowledge about agriculture and lack of support for soil management and integrated plant-nutrient systems. Focusing on the importance and need for soil-fertility management, a soil-testing mobile van program has recently been introduced in Nepal by Soil Management Directorate, Hariharbhawan. With the introduction of the mobile lab, famers can get their soil tested for nutrient deficiencies and fertilizer requirements at their doorsteps. Using mobile lab, spatial distributions of chemical properties, including pH, organic matter (OM), total nitrogen (N), available phosphorus (as P_2O_5), and available potassium (as K_2O) were examined in soil samples taken from the 0 to 15 cm depth from selected agricultural fields in eight different districts in the mid-hills and Terai regions of Nepal. Tests conducted on 1,479 soil samples in the soil-testing mobile van revealed the following: the mean soil OM ranged from 0.01 to 1.77%; total N content ranged from 0.01 to 0.08%; mean available P_2O_5 ranged from 16.47 to 197.82 kg ha^{-1}; and mean available K_2O

ranged from 84.3 to 422.57 kg ha^{-1}. For each crop to be grown, farmers were provided with individual soil health reports and fertilizer recommendations (rate, amount, and type). This program not only allows scientists and farmers to work closely and share information but also serves as a model for the nation to successfully transfer technology for improving soil health and sustainability.

Keywords: Integrated plant nutrient system, mobile lab, smallholder farmers, soil fertility, sustainability

Introduction

Nepal can be broadly divided into three ecological zones: Terai (plain), mid-hills, and high-hills. Because of the advantages of tropical and sub-tropical climates in the Terai region, cereal crops can be extensively grown. The main crops grown include rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), potato (*Solanum tuberosum* L.), sugarcane (*Saccharum* spp.), and various pulses. Cash crops, such as tea (*Camellia sinensis*), coffee (*Coffee arabica*), ginger (*Zingiber officinale*), and many kinds of vegetables, are the most dominant in mid-hills. The high-hills region is most suitable for livestock production; soils in these areas being sandy, dry, and highly prone to wind erosion are unsuitable for crop production. In an ecological context, the country has great prospects for agricultural diversification (Panday 2012; Paudel et al. 2014; Sharma 2001).

Agriculture in Nepal is still largely subsistence in nature and dominated by smallholder farmers and mixed cropping systems. Many studies have shown that a decline in soil fertility across the country is a key factor that constrains the productivity of most crops and farming systems (Balla et al. 2014; Rijal 2001; Schreier, Brown, and Shah 1995). There are a variety of other causes that are responsible for the stagnant productivity; for example, climatic variations (Panday 2012), changing farming practices (Ghimire and Panday 2017; Paudel et al. 2014), and soil erosion (Maharjan and Joshi 2013). The national average for the use of chemical fertilizer has increased dramatically from 16.7 kg ha^{-1} in 2002 to 67.4 kg ha^{-1} in 2014 (WBG 2017). However, chemical fertilizer use in Nepal is still relatively low compared with other Asian countries. Farmers use 2.5 to 3 t ha^{-1} of organic manure annually for soil-fertility management (NARC 2013).

The Department of Agriculture under the Ministry of Agricultural Development (MOAD) in Nepal implements many programs to focus on the importance of and need for soil-fertility management. Such programs include promotion of organic manure and compost, green manuring, balanced use of chemical fertilizers, soil-testing services, farmers' field school regarding integrated plant-nutrient system, distribution of rhizobium inoculation packets, and other trainings and demonstrations. Of these, soil-testing service is one of the high priority programs. Soil-testing is an important diagnostic tool to assess nutrient sufficiency in plants. One of the objectives of soil sampling is to distinguish nutrient-deficient areas from nutrient-sufficient areas (Marx, Hart, and Stevens 1999). Fertilizer recommendations are only as good as the accuracy of the soil tests on which they are based (Rosen, Bierman, and Eliason 2008). There are many soil-testing laboratories in Nepal, including those operated by government and nongovernmental organizations. However, farmers must travel to these labs to get their soil samples analyzed. This can be very difficult because the laboratories are located in the district headquarters or in the country's capital city.

Soil-testing mobile van

A soil-testing mobile van (also called mobile lab) was introduced in Nepal in 2014. It was gifted to the MOAD, Nepal, by Paradeep Phosphate Limited of Odisha, India. With the introduction of the mobile lab, famers will now be able to have their soil samples tested for nutrient deficiencies and fertilizer requirements at their doorsteps. Such programs have recently been introduced in other countries as well. For example, in India, mobile labs began functioning in 2012 under the Manav Vikas Mission mobile soil-testing laboratory program, and 'Soilcares' initiative implemented mobile labs in Kenya in 2014.

The mobile soil-testing labs are much like the stationary laboratories with regard to staff, type of equipment, facilities, and soil-testing methods. In such labs, all the major soil-testing equipment, including spectrophotometer, flame photometer, colorimeter, pH meter, electric shaker, magnetic stirrer, weighing machine, and any necessary glass wares, are available. In addition, information about soil-management practices is presented to farmers in the form of documentaries and films.

Generally, a mobile soil camp stays in a place for less than a week. However, farmers' demand for soil-testing is quite high and the capacity of a soil-testing mobile van is 40 samples per day. Farmers are instructed on how to take soil samples through documentaries and multimedia on the first day of the camp. Then, the farmers bring their soil samples to be tested. The samples are prepared on the spot using a grinder and sieve. The fine soil, after sieving, is used to analyze pH, organic matter (OM), total nitrogen (N), available phosphorus (as P_2O_5), and available potassium (as K_2O).

On the final day, farmers are provided with soil-health reports and recommendations. These reports include both quantitative and qualitative results (i.e., very low, low, medium, high, and very high). Thus, farmers get to know the nutrient status of their fields and can follow the suggested recommendations. If the recommended soil-management practices are followed properly, soil-fertility can be improved. The objective of this investigation was to explain the status of soil-fertility programs, introduce soil-testing mobile van, and provide information on soil-testing success from eight different districts for four different commodities (rice, maize, potato, and vegetables). Recommendations for fertilizers and soil amendments in Nepal are described.

Methodology

Soil sampling locations

Nepal is split into 75 districts and has four seasons: pre-monsoon (March to May), monsoon (June to September), post-monsoon (October to November), and winter (December to February). Monsoon is the main source of precipitation, which accounts for 85% of total annual rainfall of 1800 mm, and the remainder 15% occurs in winter (Panday 2012).

Fragmentation of arable land being a major barrier for agriculture commercialization and mechanization in the country, the MOAD has classified land-holdings as pockets (at least 10 ha of land), blocks (100 ha of land), zones (500 ha of land), and superzones (1000 ha of land) to address the issue of fragmentation of arable land through the Prime Minister Agriculture Modernization Project (PMAMP) in the fiscal budget 2016–2017. The government has planned for further development of large-sized agricultural production areas, commercial agricultural areas, agri-processing centers, and agri-industrial areas for pockets, blocks, zones, and superzones, respectively.

In the first phase of the soil-testing mobile van program, Soil Management Directorate (SMD) of MOAD has selected one block, two zones, and two superzones to support farmers through PMAMP. The details of the categories, commodities, and districts included rural municipality (RM), municipality (M), or metropolitan (Mp) and the number of samples for the first phase of the soil-testing mobile van program are given in **Table 1**. Study locations are shown in **Figure 1**. The study was carried out from August 2016 to April 2017.

Sample collection and analyses

The interested farmers in the selected location were trained by the extension workers to collect soil samples prior to conducting soil analyses at the mobile van facility. In addition, soil analysis team used multimedia and films to demonstrate soil sampling methods to farmers on the first day of the

Table 1. Commodities, sampling locations and number of sample collections during soil-testing mobile van program in Nepal.

Category	*Commodity*	*Ecological zone*	*District*	*Location area*	*Number of samples*
Superzone	Rice	Terai	Jhapa	Kechankebal RM†	219
Block	Rice	Terai	Nawalparasi	Sunwal M‡	86
		Terai	Morang	Sundar Haraincha M‡	40
		Terai	Saptari	Rupani RM †	40
		Terai	Sunsari	Inaruwa M‡	40
Superzone	Potato	Mid-hills	Kavreplanchowk	Banepa M‡	219
Zone	Maize	Mid-hills	Dhading	Nilkantha M‡	201
	Vegetable	Mid-hills	Dhading	Benighat Rarang RM†	143
				Gajuri RM†	109
				Dhunibesi M‡	101
		Terai	Chitwan	Bharatpur Mp§	241
Total =					1479

† Rural Municipality
‡ Municipality
§ Metropolitan

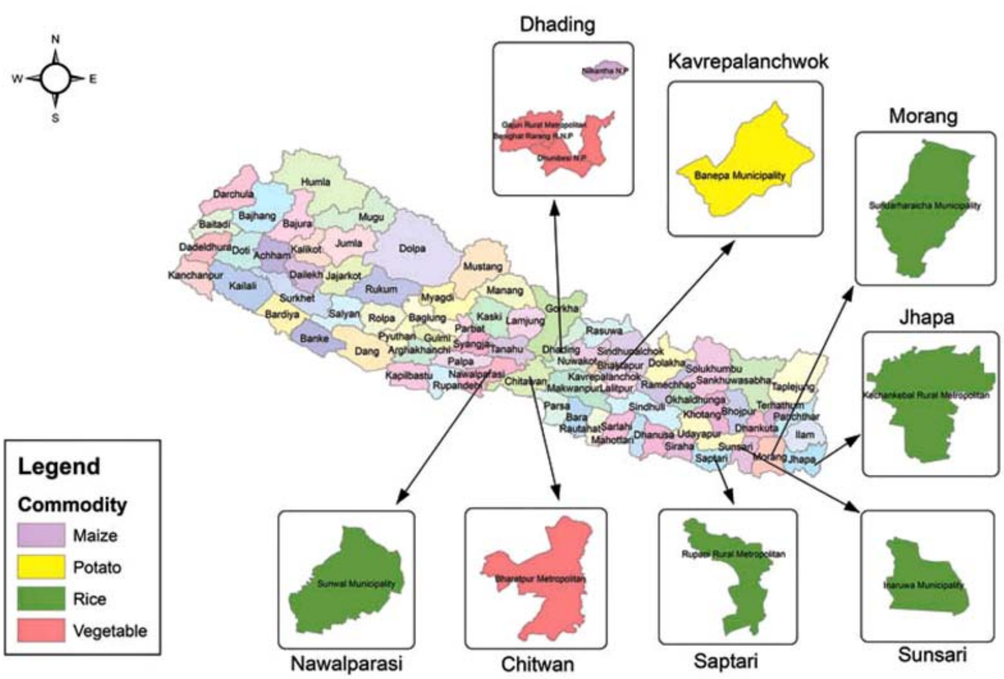

Figure 1. Locations of soil sample collection.

soil-testing camp. To maintain sample uniformity, farmers were encouraged to bring samples from their own topsoil layer (0 to 15 cm depth).

The soil chemical parameters tested and methods used are given in **Table 2.** In general, the sampling, processing, and analysis of the soil samples in the mobile lab were carried out with the same procedures and methods as used in a stationary lab. However, N was determined by multiplying the OM value with 0.05, under the assumption that OM contains 5% N. Extractant used for available P_2O_5 was $NaHCO_3$ and that for available K_2O was $C_2H_7NO_2$. Preparation of soil analysis reports and recommendations were also performed in a similar manner as in the case of a stationary laboratory and were made available to farmers at the camp site.

Table 2. Methods used for testing of soil chemical parameters in soil-testing mobile van in Nepal.

Test	*Method*
pH	1:2 soil water suspension (Jackson 1973)
Organic matter (OM, %)	Walkely and Black (Walkley and Black 1934)
Total nitrogen (N, %)	OM × 0.05
Available phosphorus (P_2O_5, kg ha^{-1})	Olsen's bicarbonate (Olsen et al. 1954)
Available potassium (K_2O, kg ha^{-1})	Flame photometry (Toth and Prince 1949)

Data analysis

Descriptive statistics (mean, standard deviation, and coefficient of variation) for soil parameters were computed using Statistix 10. Ratings for pH and nutrient values (OM, N, P_2O_5, and K_2O) based on standards recommended by Nepal Agricultural Research Council, Nepal (NARC 2013) and used by Soil Management Directorate are shown below:

pH: Highly acidic <4.5, Acidic = 4.5 to 5.5, Slightly acidic = 5.5 to 6.5, Neutral = 6.5 to 7.5, and Alkaline >7.5

OM: Very high >10, High = 5 to 10,Medium= 2.5 to 5, Low = 1 to 2.5, and Very low <1

N: Very high >0.4, High = 0.2 to 0.4, Medium = 0.1 to 0.2, Low = 0.05 to 0.1, and Very low <0.05

P_2O_5: Very high >110, High = 55 to 110, Medium = 30 to 55, Low = 10 to 30, and Very low <10

K_2O: Very high >500, High = 280 to 500, Medium = 110 to 280, Low = 55 to 110, and Very low <55

The nutrient index was determined via the following formula given by Ramamurthy and Bajaj (1969):

$$\text{Nutrient index (NI)} = [(N_L \times 1) + (N_M \times 2) + (N_H \times 3)]/N_T$$

where N_L, N_M, and N_H are number of samples falling in low (low and very low), medium, and high (high and very high) classes of nutrient status, respectively; and N_T is the total number of samples analyzed for a given area. The resulting NIs were characterized as low (<1.67), medium (1.67 to 2.33), and high (>2.33).

Results and discussion

Summary statistics and rating of soil chemical parameters

Table 3 contains summary statistics for soil chemical properties, including pH, OM (%), N (%), P_2O_5 (kg ha^{-1}), and K_2O (kg ha^{-1}), from different locations. Results showed that pH ranged from 5.2 (in Jhapa district, rice superzone) to 7.9 (in Saptari district, rice block). Of the 1,479 samples for pH, 164 samples were alkaline, 544 samples were neutral, 566 samples were slightly acidic, 188 samples were acidic, and 17 samples were highly acidic (**Table 4**). Most of the soils in Nepal are acidic in nature because of the dominant parent material (such as sandstone, siltstone, quartzite, and shale), natural vegetation, and loss of major cations because of high precipitation (Ghimire and Bista 2016). Plant growth and most soil processes are favored by a specific soil pH range. Acidic soil, particularly subsurface soil, will restrict plant roots' access to water and nutrients (Gazey and Davies 2009). Our observation of higher acidity in the Jhapa district than in Saptari and Nawalparasi districts may be associated with the loss of basic cations during the monsoon season. Though, all three districts are in Terai region, eastern part of Nepal (i.e. Jhapa district) gets more precipitation than central (i.e. Saptari district), and western (i.e. Nawalparasi district) regions. Other possible influences would include the type and history of fertilizer application, crop residue management, and nutrient uptake and crop harvest without replenishing nutrient across time (Bremner and Mulvaney 1982).

Soil OM ranged from 0.24% (in Sunsari district, rice zone) to 1.81% (in Morang district, rice block). The competing use of crop residues as animal feed limits nutrient return to the soil, and the sparse vegetation and intensive cropping generally account for the reduction of OM in the soil. Soil OM not only plays a major role in soil-fertility by affecting physical and chemical properties, but it also controls soil-microbial activity by serving as a

Table 3. Summary statistics for selected soil chemical parameters from soil-testing mobile van program in Nepal.

	pH	*OM*¶	*N*#	*P_2O_5*††	*K_2O*‡‡
Rice					
Kechankebal RM† Jhapa (n = 219)					
Mean	5.2	0.71	0.04	51.22	157.82
SD	0.4	0.38	0.02	60.51	118.74
CV (%)	7.7	54.76	54.76	108.74	76.67
Sunwal M‡ Nawalparasi (n = 86)					
Mean	7	1.77	0.09	22.98	85.45
SD	0.9	1.07	0.05	20.49	59.1
CV (%)	12.2	60.48	60.48	89.15	69.16
Sundari Haraincha M‡ Morang (n = 40)					
Mean	6.9	1.81	0.09	56.2	84.3
SD	0.5	0.62	0.03	29.53	41.15
CV (%)	7.5	34.33	34.33	52.55	48.81
Rupani RM† Saptari (n = 40)					
Mean	7.9	1.17	0.06	16.47	135.3
SD	0.2	0.49	0.02	8.64	23.86
CV (%)	2	42.1	42.1	52.49	17.63
Inaruwa M‡ Sunsari (n = 40)					
Mean	5.9	0.24	0.01	60.81	167.52
SD	0.6	0.06	-	60.84	211.72
CV (%)	9.7	26.48	26.48	100.06	126.38
Potato					
Banepa M‡ Kavreplanchowk (n = 219)					
Mean	6.4	1.29	0.06	102.06	220.78
SD	0.7	0.74	0.04	78.2	206.4
CV (%)	10.9	57.11	57.11	76.63	93.49
Maize					
Nilkantha M‡ Dhading (n = 201)					
Mean	6	1.6	0.08	37.24	207.76
SD	0.5	0.81	0.04	57.07	182.11
CV (%)	8.7	50.56	50.56	153.23	87.65
Vegetable					
Benighat Rarang RM† Dhading (n = 143)					
Mean	6.8	0.8	0.04	150.19	215.33
SD	0.5	0.35	0.02	133.4	172.98
CV (%)	7.1	44.08	44.08	106.42	78.97
Gajuri RM† Dhading (n = 109)					
Mean	6.8	0.66	0.03	58.24	422.57
SD	0.7	0.39	0.02	121.7	395.19
CV (%)	9.7	58.7	58.7	208.96	93.52
Dhunibesi M‡ Dhading (n = 101)					
Mean	6.3	0.87	0.04	57.54	283.84
SD	0.6	0.45	0.02	55.5	353.24
CV (%)	9.8	51.62	51.62	96.47	124.45
Bharatpur Mp § Chitwan (n = 241)					
Mean	6.8	1.14	0.06	197.82	234.55
SD	0.5	0.77	0.04	157.33	196.38
CV (%)	7.3	65.42	65.42	80.37	85.16

† Rural Municipality
‡ Municipality
§ Metropolitan
¶ Organic matter, in %
# Total nitrogen, in %
†† Available phosphorus, in kg ha^{-1}
‡‡ Available potassium, in kg ha^{-1}

Table 4. Number of samples under different pH rating categories from soil-testing mobile van program in Nepal.

	Alkaline	*Neutral*	*Slightly acidic*	*Acidic*	*Highly acidic*	*Total*
Rice						
Kechankebal RM†, Jhapa	1	5	71	125	17	219
Sunwal M‡, Nawalparasi	24	37	23	2	-	86
Sundari Haraincha M‡, Morang	3	25	12	-	-	40
Rupani RM†, Saptari	-	6	28	6	-	40
Inaruwa M‡, Sunsari	38	2	-	-	-	40
Potato						
Banepa M‡, Kavreplanchowk	8	95	96	20	-	219
Maize						
Nilkantha M‡, Dhading	40	59	83	19	-	201
Vegetable						
Benighat Rarang RM†, Dhading	18	54	68	3	-	143
Gajuri RM†, Dhading	17	62	68	2	-	109
Dhunibesi M‡, Dhading	1	28	62	10	-	101
Bharatpur Mp§, Chitwan	14	171	55	1	-	241
Total	164	544	566	188	17	1479

† Rural Municipality
‡ Municipality
§ Metropolitan

source of carbon and N mineralization (Yeshaneh 2015). Intensive cropping observed in the study area (plantation of one to four crops within a year) has removed essential plant nutrients from the soil, thereby exerting pressure on soil fertility. Inclusion of legumes or cover crops in cropping system could be helpful in compensating for depletion of nutrients, compared with the addition of chemical fertilizers only. However, most of the farmers do not follow such a practice. Agricultural soils in these locations receive organic manure annually, which may improve soil fertility, minimize soil acidity, and favor plant growth. The present rate of organic manure application is far below the global average (Bishwakarma et al. 2014), which might not meet the crop demand on a long-term basis (Regmi 2000).

As OM decreases, so do total N, available P_2O_5, available K_2O, and some micronutrients (Wang et al. 2006). Total N ranged from 0.01% (in Sunsari district, rice zone) to 0.08% (in Dhading district, maize zone). Total N content was very low (<0.05%) in more than half of the tested samples, which could be because of increased rate of mineralization and insufficient application of N fertilizer to nutrient-exhausting crops, such as wheat and maize (Goovaerts 1999). Available P_2O_5 ranged from 16.47 kg ha^{-1} (in Saptari district, rice zone) to 197.82 kg ha^{-1} (in Chitwan district, vegetable zone). The relatively higher availability of P_2O_5 observed as compared with OM and N could be caused by the dissolution of calcium–phosphorus under neutral soil reaction, as well as less erosion and runoff at that location (Pal, Wani, and Sahrawat 2012). Similarly, available K_2O ranged from 84.3 kg ha^{-1} (in Morang district, rice zone) to 422.57 kg ha^{-1} (in Dhading district, vegetable zone). In general, soils in Terai region ranged from acidic to neutral pH among the selected locations. Of the total samples, 759 samples (53%) were very low (OM: <1% and N: <0.05) in OM and total N, 449 samples (31%) were low in available P_2O_5, and 286 samples (45%) were medium in available K_2O. Details regarding pH rating (alkaline, neutral, slightly acidic, acidic, and highly acidic) and nutrient values (very low, low, medium, high, and very high) are given in **Tables 4 and 5** based on the number of soil samples from locations.

Table 5. Number of samples under different soil chemical nutrient rating categories from soil-testing mobile van program in Nepal.

	Very low	*Low*	*Medium*	*High*	*Very high*
Rice					
Kechankebal RM†, Jhapa (n = 219)					
OM¶	167	52	–	–	–
N#	167	50	2	–	–
P_2O_5††	25	107	37	36	14
K_2O‡‡	23	68	106	15	7
Sunwal M‡, Nawalparasi (n = 86)					
OM¶	21	43	22	–	–
N#	21	39	24	2	–
P_2O_5††	21	44	14	7	–
K_2O‡‡	27	44	14	1	–
Sundari Haraincha M‡, Morang (n = 40)					
OM¶	1	34	5	–	–
N#	1	25	14	–	–
P_2O_5††	1	2	18	16	3
K_2O‡‡	4	32	3	1	–
Rupani RM†, Saptari (n = 40)					
OM¶	13	26	1	–	–
N#	13	25	2	–	–
P_2O_5††	–	38	1	1	–
K_2O‡‡	–	5	35	–	–
Inaruwa M‡, Sunsari (n = 40)					
OM¶	40	–	–	–	–
N#	40	–	–	–	–
P_2O_5††	–	12	17	5	6
K_2O‡‡	9	13	12	3	3

Table 5 (continued). Number of samples under different soil chemical nutrient rating categories from soil-testing mobile van program in Nepal.

	Very low	*Low*	*Medium*	*High*	*Very high*
Potato					
Banepa M‡, Kavreplanchowk (n = 219)					
OM¶	83	118	18	–	–
N#	83	98	37	1	–
P_2O_5††	11	25	40	65	78
K_2O‡‡	27	47	92	30	23
Maize					
Nilkantha M‡, Dhading (n = 201)					
OM¶	43	127	31	–	–
N#	43	98	59	1	–
P_2O_5††	22	111	31	29	8
K_2O‡‡	10	53	96	29	13
Vegetable					
Benighat Rarang RM†, Dhading (n = 143)					
OM¶	105	38	–	–	–
N#	105	38	–	–	–
P_2O_5††	20	31	19	21	52
K_2O‡‡	7	29	74	20	13
Gajuri RM†, Dhading (n = 109)					
OM¶	88	21	–	–	–
N#	88	20	1	–	–
P_2O_5††	31	25	18	22	13
K_2O‡‡	2	7	39	33	28
Dhunibesi M‡, Dhading (n = 101)					
OM¶	62	39	–	–	–
N#	62	37	2	–	–
P_2O_5††	5	35	19	29	13
K_2O‡‡	10	22	36	19	14
Bharatpur Mp§, Chitwan (n = 241)					
OM¶	136	97	7	1	–
N#	136	87	13	5	–
P_2O_5††	1	19	17	55	149
K_2O‡‡	9	25	147	39	21
Total (n = 1479)					
OM¶	759	595	83	2	–
N#	759	517	153	10	-
P_2O_5††	137	449	231	286	336
K_2O‡‡	128	345	654	190	122

† Rural Municipality
‡ Municipality
§ Metropolitan
¶ Organic matter, in %
# Total nitrogen, in %
†† Available phosphorus, in kg ha^{-1}
‡‡ Available potassium, in kg ha^{-1}

Nutrient indexing of soil chemical parameters

Nutrient indices were calculated to determine the status of OM, total N, available P_2O_5, and available K_2O at the district level on the basis of the commodity for block, zone, or superzone. There was a sharp decrease in OM and total N in all districts, ranging from 1 to 1.27 and 1 to 1.35 respectively, representing low nutrient indices (**Table 6**). The available P_2O ranged from low (in Jhapa, Nawalparasi, Sunsari, and Dhading districts) to high (in Morang, Kavreplanchowk and Chitwan districts) nutrient indices; whereas, available K_2O ranged from low (in Nawalparasi, Morang and Saptari districts) to medium (in Jhapa, Sunsari, Kavreplanchowk, Dhading, and Chitwan districts) nutrient indices (Table 6). In general, soil nutrient indices, which were at low or medium levels, would need a relatively higher amount of fertilizer application than those at a high level. However, nutrient management for sustained crop growth and yield should be focused on OM management, as it is closely associated with soil macro- and micro-nutrients.

Fertilizer recommendations

The soil-health report and fertilizer recommendations sheet included all information provided by farmers for the identification of soil samples. The

Table 6. District-wide nutrient indices for different agro block, zone and superzone from soil-testing mobile van program in Nepal.

	OM†		*N*‡		*P_2O_5*§		*K_2O*¶	
	Value	*Remark*	*Value*	*Remark*	*Value*	*Remark*	*Value*	*Remark*
Rice								
Jhapa	1	Low	1.01	Low	1.63	Low	1.68	Medium
Nawalparasi	1.27	Low	1.34	Low	1.33	Low	1.19	Low
Morang	1.13	Low	1.35	Low	2.4	High	1.13	Low
Saptari	1	Low	1	Low	1.98	Medium	1.6	Low
Sunsari	1.02	Low	1.05	Low	1.08	Low	1.88	Medium
Potato								
Kavreplanchowk	1.08	Low	1.18	Low	2.49	High	1.9	Medium
Maize								
Dhading	1.15	Low	1.3	Low	1.52	Low	1.9	Medium
Vegetable								
Dhading	1	Low	1.01	Low	2.01	Medium	2.14	Medium
Chitwan	1.04	Low	1.1	Low	2.76	High	2.11	Medium

† Organic matter
‡ Total nitrogen
§ Available phosphorus
¶ Available potassium

recommendations sheet has two parts: the soil-health status based on previously grown crop and fertilizer recommendation for the crop to be grown. Soil tests are most commonly used to predict the likelihood of crop yield responses to inputs of fertilizers and lime. However, Nepalese farmers have scant knowledge of soil physico-chemical properties, which is necessary to develop yield goals across different cropping systems. Fertilizer calculations are often excluded and application rates are adjusted on the basis of climate and soil properties at a specific location.

The recommendations sheet provides additional information about the method of fertilizer application; for example, a half dose of recommended nitrogenous fertilizer, full dose of the phosphatic and potassic fertilizers to be applied as a basal dose, and the remainder half dose of nitrogenous fertilizer as split application per crop type. For Nepalese farmers, the most commonly recommended chemical fertilizers by SMD were urea (46% nitrogen) and/or ammonium sulfate (21% nitrogen and 26% sulfur) as nitrogenous sources, di-ammonium phosphate (18% nitrogen and 46% phosphorus) as a phosphatic source, and muriate of potash (60% potassium and 40% chlorine) or potassium sulfate (40 to 44% of potassium and 18% of sulfur) as potassic sources. In addition, farmers were encouraged to apply agricultural lime to ameliorate acidic soils, at least 2–3 weeks before planting time (NARC 2013). Details about soil pH range and recommended agricultural lime rate are given in **Table 7**. Similarly, recommended doses of chemical fertilizers for specific crops are given in **Table 8**. Because of the small farm size, which is common in Nepal, recommendations are made in kg ropani^{-1}, where 20 ropani = 1 hectare.

Table 7. Recommended dose of agricultural lime for Mid-hills and Terai region of Nepal.

	Mid-hills (kg ropani^{-1})			*Terai (kg ropani^{-1})*		
pH	*Sandy loam*	*Loam*	*Clay*	*Sandy loam*	*Loam*	*Clay*
5.9	85	110	146	45	62	128
5.8	97	128	166	52	72	146
5.7	108	142	188	58	82	166
5.6	119	158	208	64	90	184
5.5	130	170	230	70	100	200
5.4	140	188	252	76	110	220
5.3	150	204	274	81	118	238
5.2	160	218	294	86	126	254
5.1	169	228	314	91	136	270
5	176	240	334	96	142	286
4.9	184	252	354	101	150	302
4.8	191	262	374	106	158	316
4.7	199	272	390	111	166	330
4.6	205	280	406	115	174	350
4.5	210	290	420	120	180	360

Table 8. Recommendation of nutrient according to the soil-testing and crop to be grown in Nepal.

	Nitrogen ($kg\ ropani^{-1}$) Nutrient Status			*Phosphorus ($kg\ ropani^{-1}$) Nutrient Status*			*Potash ($kg\ ropani^{-1}$) Nutrient Status*		
Crop	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
Rice (irrigated)	5	2.5	1.25	1.5	0.75	0.38	1.5	0.75	0.38
Rice (rainfed)	3	1.5	0.75	1	0.5	0.25	1	0.5	0.25
Maize (rainy season)	3	1.5	0.75	1.5	0.75	0.38	1.5	0.75	0.38
Maize (winter season)	4.5	2.25	1.13	2.25	1.13	0.56	2.25	1.13	0.56
Potato	11	5.5	2.75	7	3.5	1.75	5	2.5	1.25
Vegetables (leafy)	10	5	2.5	9	4.5	2.25	4	2	1
Vegetables (root)	10	5	2.5	9	4.5	2.25	4	2	1
Green pea	0.75	0.38	0.19	2	1	0.5	6	3	1.5
Cucumber	7	3.5	1.75	2	1	0.5	5	2.5	1.25
Summer squash	12	6	3	9	4.5	2.25	3	1.5	0.75
Tomato (Srijana variety)	10	5	2.5	9	4.5	2.25	4	2	1
Tomato (dwarf variety)	10	5	2.5	10	5	2.5	7.5	3.75	1.88
Brinjal	10	5	2.5	9	4.5	2.25	4	2	1
Lady's finger (okra)	10	5	2.5	9	4.5	2.25	3	1.5	0.75
Cauliflower (local)	10	5	2.5	6	3	1.5	4	2	1
Cauliflower (hybrid)	10	5	2.5	6	3	1.5	5	2.5	1.25
Cabbage	12	6	3	9	4.5	2.25	4	2	1
Bean	4	2	1	6	3	1.5	3	1.5	0.75
Bitter gourd	10	5	2.5	6	3	1.5	3	1.5	0.75
Cowpea	4	2	1	6	3	1.5	2	1	0.5
Bell pepper	10	5	2.5	5	2.5	1.25	5	2.5	1.25
Onion	12	6	3	9	4.5	2.25	4	2	1

Conclusion

In general, the results from mobile lab analysis of 1,479 farmers' soil samples in eight different districts of Nepal revealed that the majority of samples had very low to low OM and total N, low to very high available P_2O_5, and low to high available K_2O contents. Similarly, the majority of samples represented slightly acidic to neutral soil pH. After analysis, for each crop to be grown, farmers were provided with individual soil health reports and fertilizer recommendations (rate, amount, and type). Based on the criteria for calculating nutrient index, soils in the study area were characterized as low for OM and total N, low to high for available P_2O_5, and low to medium for available K_2O. This study showed that the soil-testing mobile van programs would be a successful way to transfer technology for soil improvement by connecting scientists and farmers.

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